Rupture history of the San Andreas fault in the Carrizo Plain: Implications for fault models and seismic hazard

Presented by

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Contributors

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J Ramon Arrowsmith

Olaf Zielke

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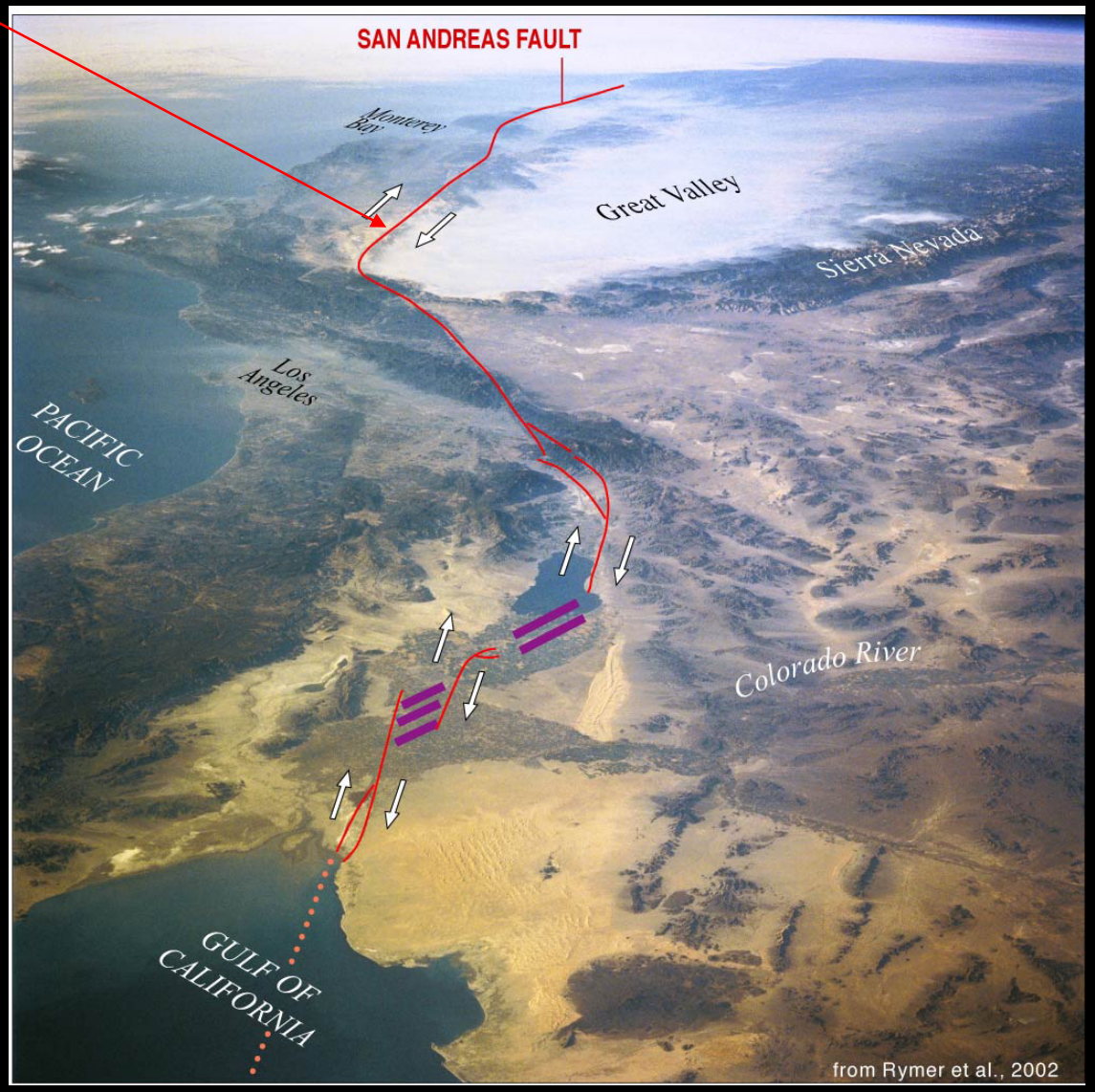
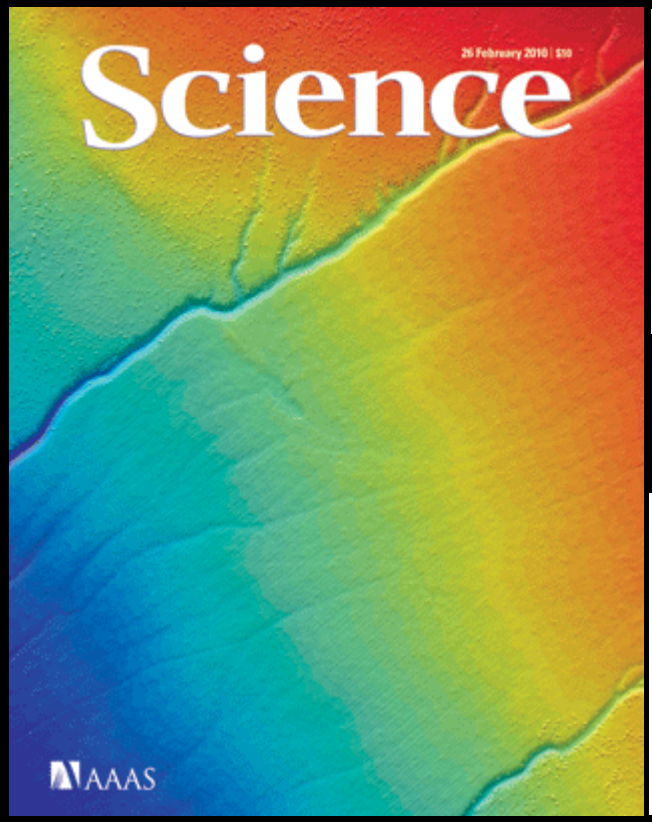
Supported by:

ERI Univ Tokyo March 16, 2010

San Andreas fault in California

- Major plate boundary fault
- Important natural laboratory for fault and fault system behavior
- Seismic hazard and risk





Sciencexpress Report

Climate-Modulated Channel Incision and Rupture History of the San Andreas Fault in the Carrizo Plain

Lisa Grant Ludwig,[1]* Sinan O. Akciz,[1] Gabriela R. Noriega,[1] Olaf Zielke,[2] J Ramón Arrowsmith[2]

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Sciencexpress Report

Slip in the 1857 and Earlier Large Earthquakes Along the Carrizo Plain, San Andreas Fault

Olaf Zielke,[1]* J Ramón Arrowsmith,[1] Lisa Grant Ludwig,[2] Sinan O. Akciz[2]

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Century-long average time intervals between ruptures of the San Andreas fault in the Carrizo Plain

S. Akciz, L. Grant Ludwig, J R. Arrowsmith and O. Zielke

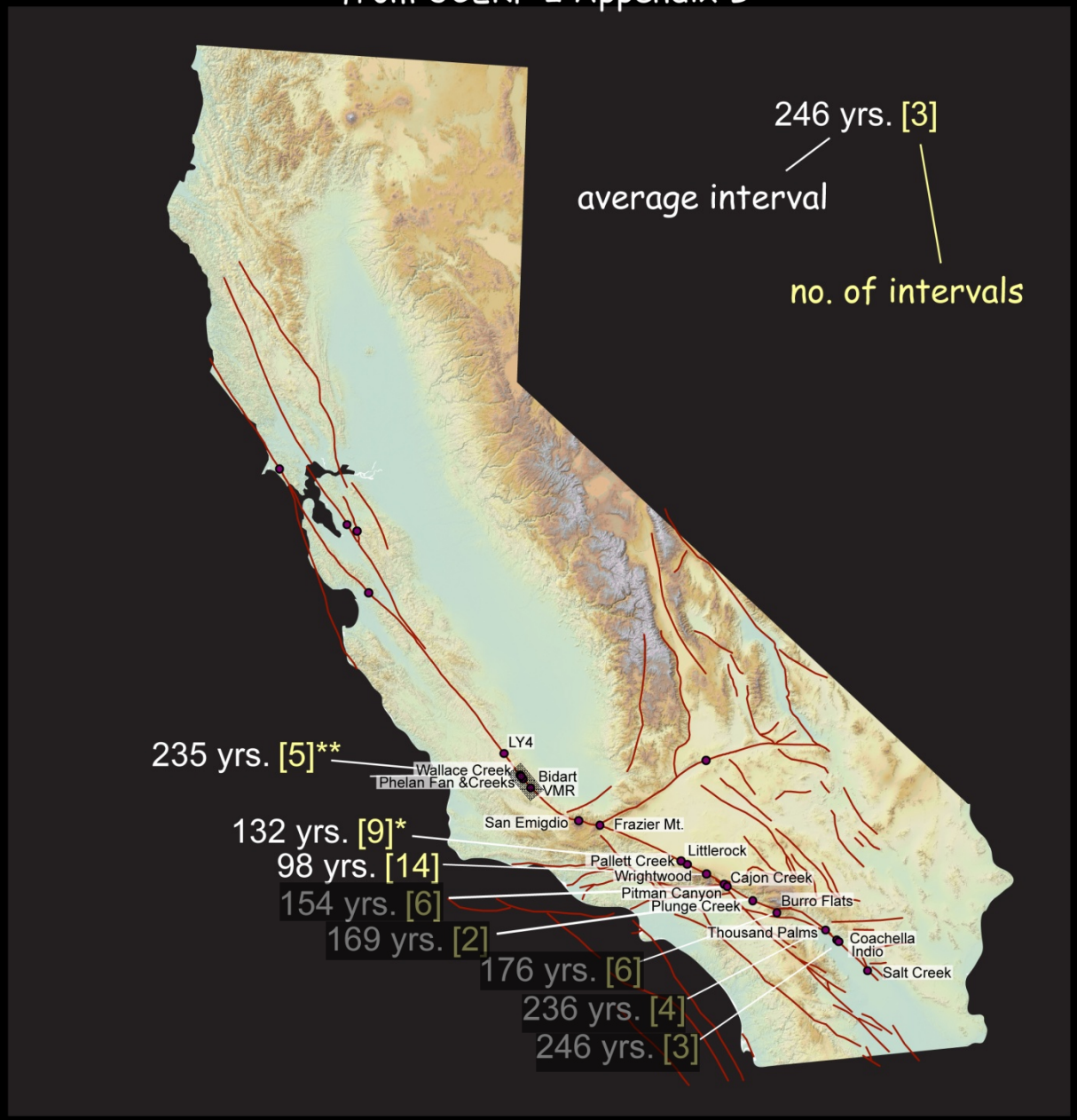
In revision for GEOLOGY

153 years since the last *Big One* on the Southern San Andreas fault
Are we

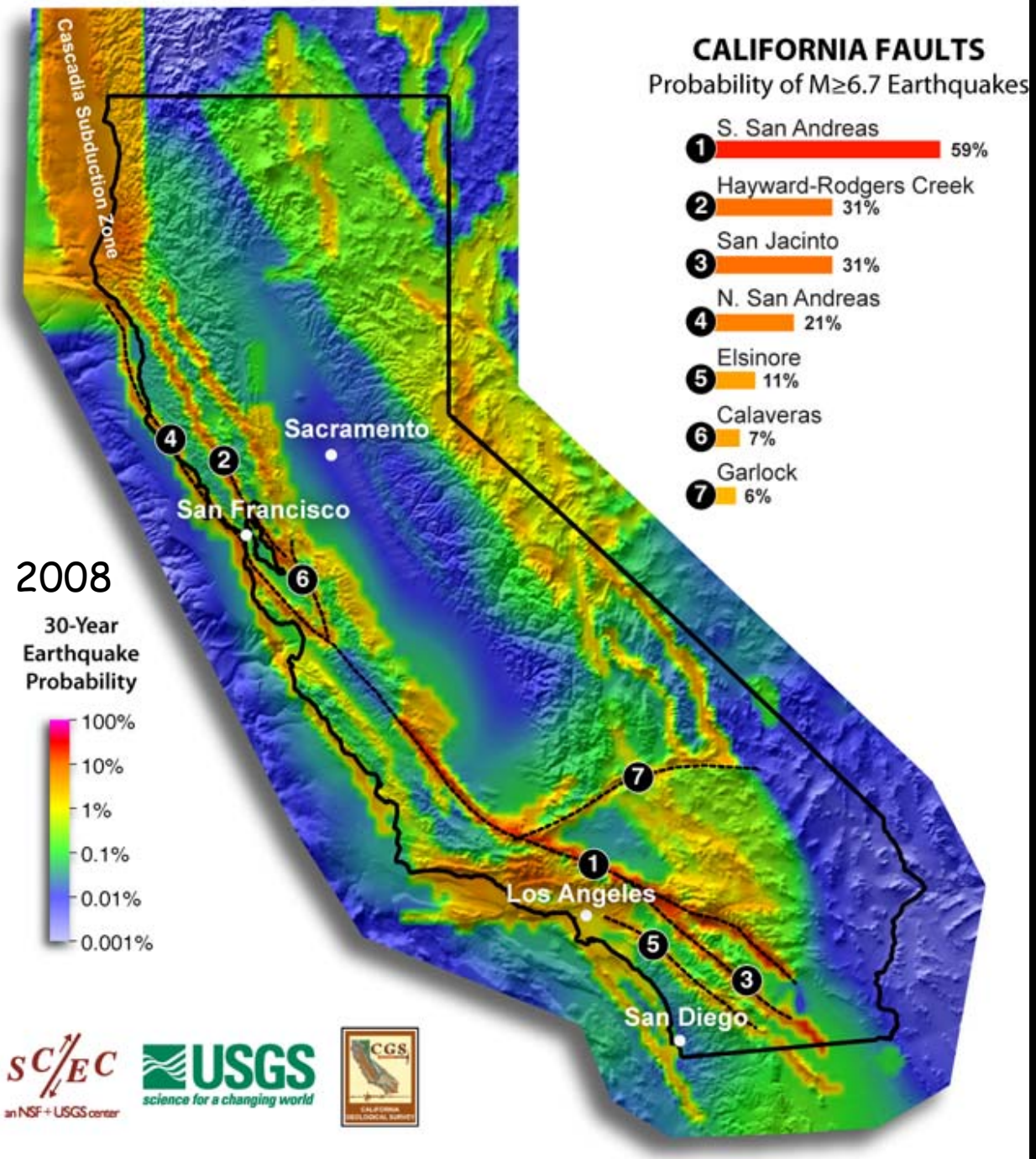
SoSAFE
SOUTHERN SAN ANDREAS FAULT EVALUATION

?

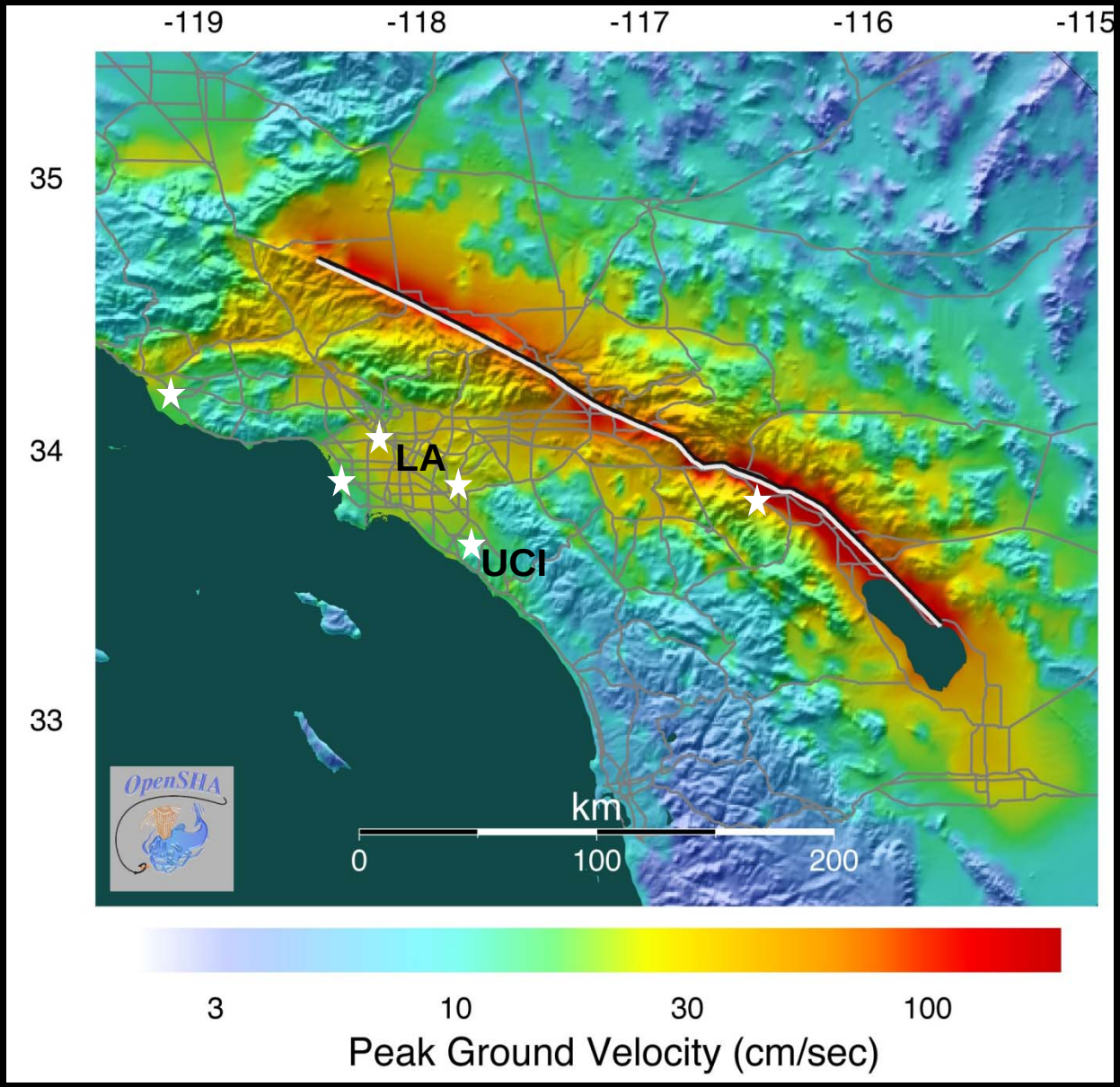
Recurrence Interval data from southern San Andreas Fault from UCERF 2 Appendix B



** combined records from Grant & Sieh (1994), Liu et al. (2004), and Sims (1994)
* from Sieh et al., 1989

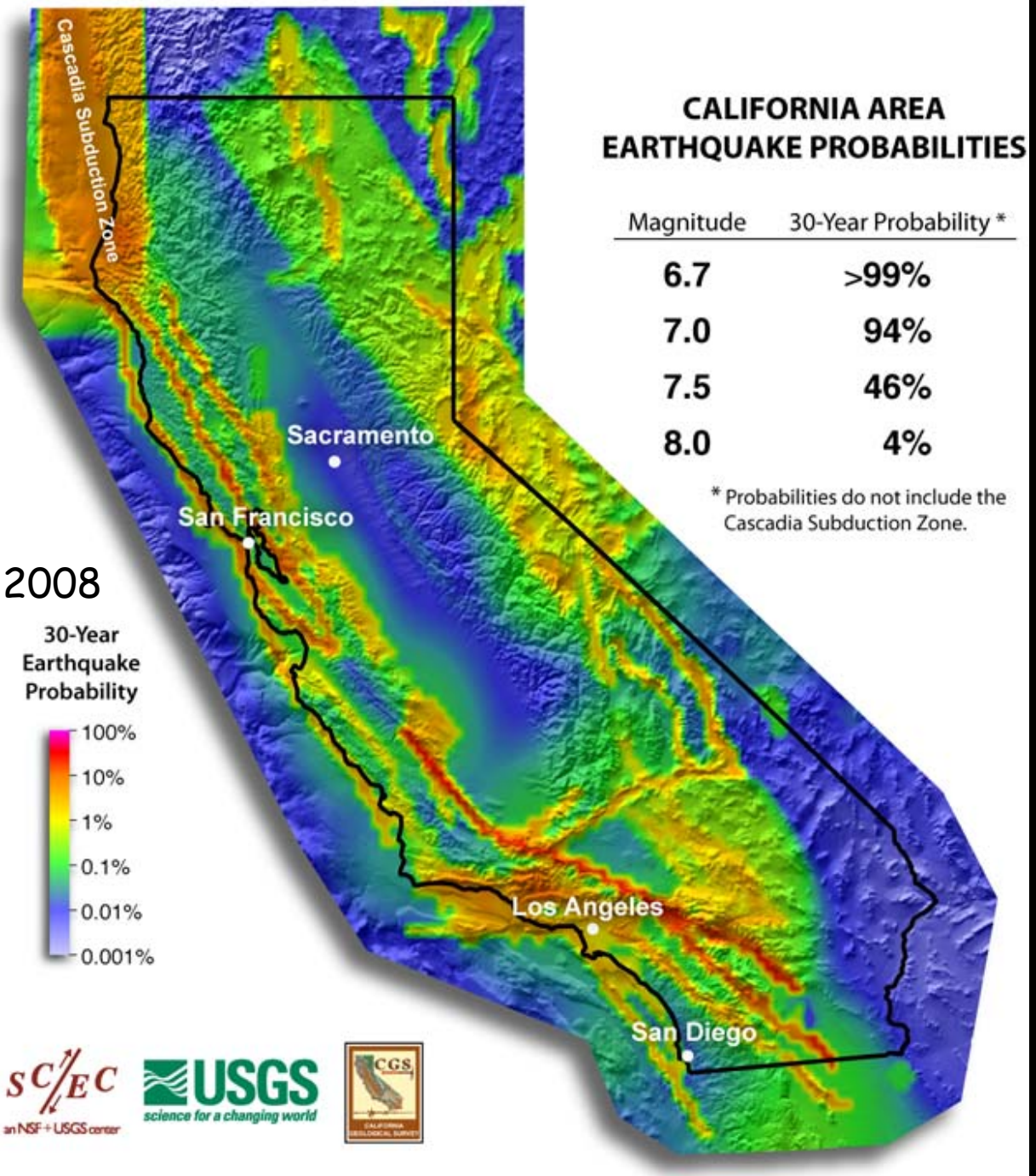

CALIFORNIA FAULTS
Probability of M≥6.7 Earthquakes
1 S. San Andreas 59%
2 Hayward-Rodgers Creek 31%
3 San Jacinto 31%
4 N. San Andreas 21%
5 Elsinore 11%
6 Calaveras 7%
7 Garlock 6%
Cascadia Subduction Zone
Sacramento
San Francisco
Los Angeles
San Diego
2008
30-Year Earthquake Probability
100%
10%
1%
0.1%
0.01%
0.001%
SCEC
an NSF+USGS center
USGS
science for a changing world
CGS

M_w7.8 'ShakeOut' Scenario *(Nov. 2008)*

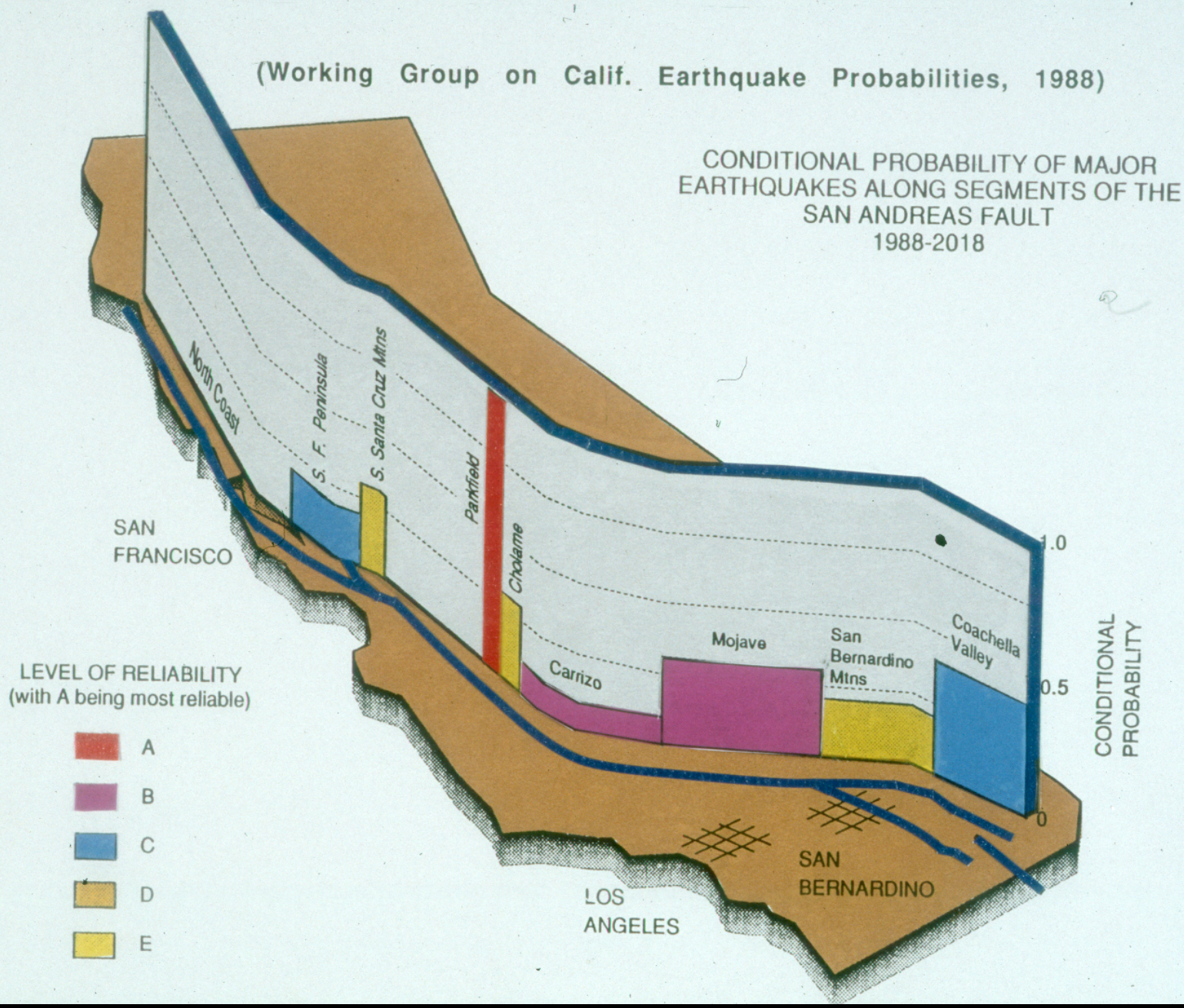


USGS science for a changing world

SCEC


Cascadia Subduction Zone
Sacramento
San Francisco
Los Angeles
San Diego
CALIFORNIA AREA
EARTHQUAKE PROBABILITIES
Magnitude
30-Year Probability *
6.7
>99%
7.0
94%
7.5
46%
8.0
4%
* Probabilities do not include the Cascadia Subduction Zone.
2008
30-Year
Earthquake
Probability
100%
10%
1%
0.1%
0.01%
0.001%
SCEC
an NSF+USGS center
USGS
science for a changing world
CGS

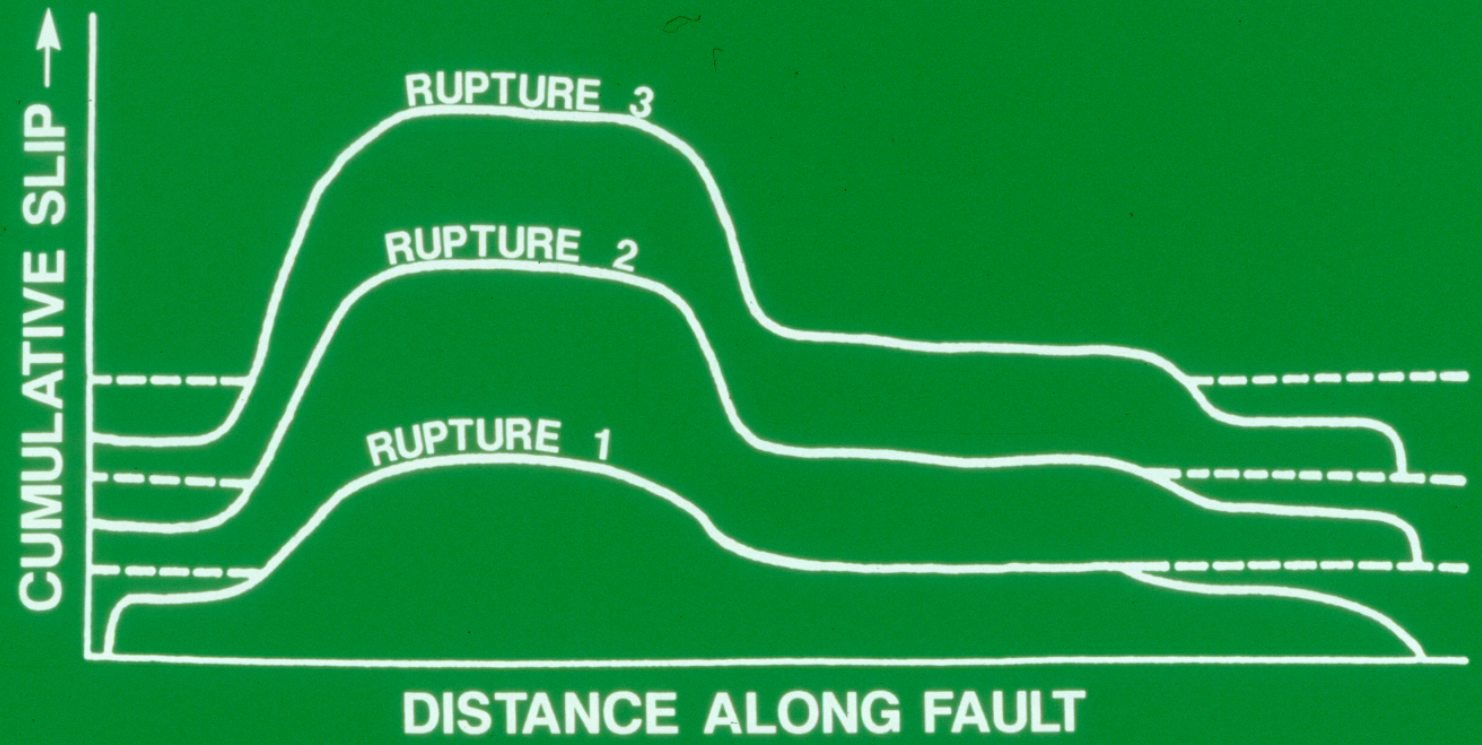
(Working Group on Calif. Earthquake Probabilities, 1988)



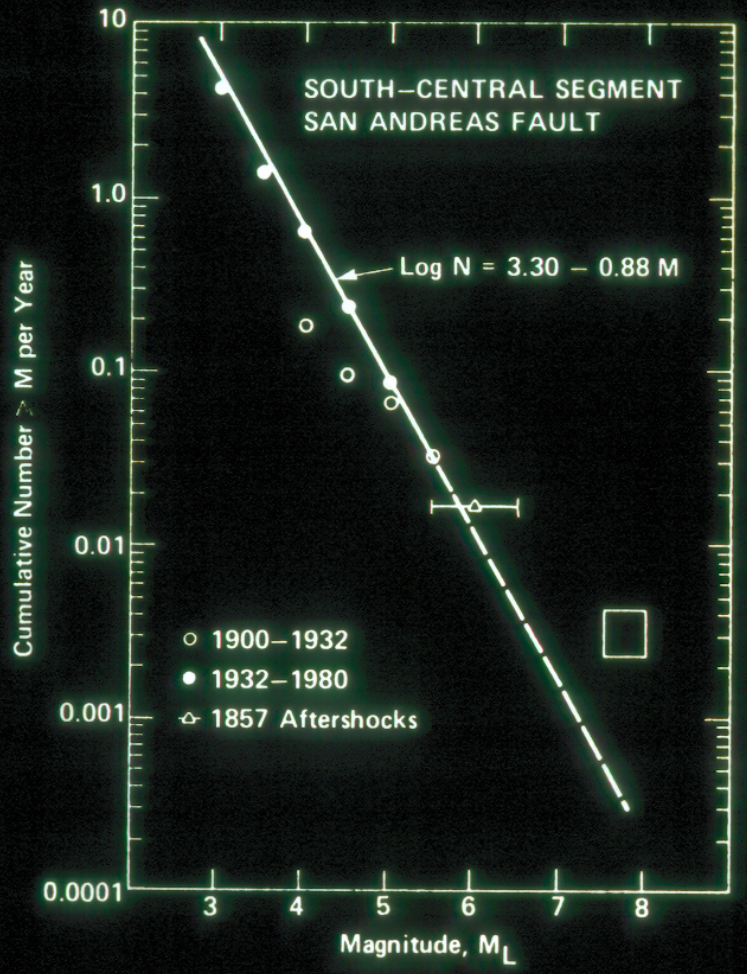
Summary of Carrizo, WGCEP 1988

- Relatively infrequent ruptures, average recurrence interval (RI) 240-450 yrs
- Large magnitude, large slip (9.5 – 12.3 m)
- Long rupture length
- Characteristic EQ and segment models

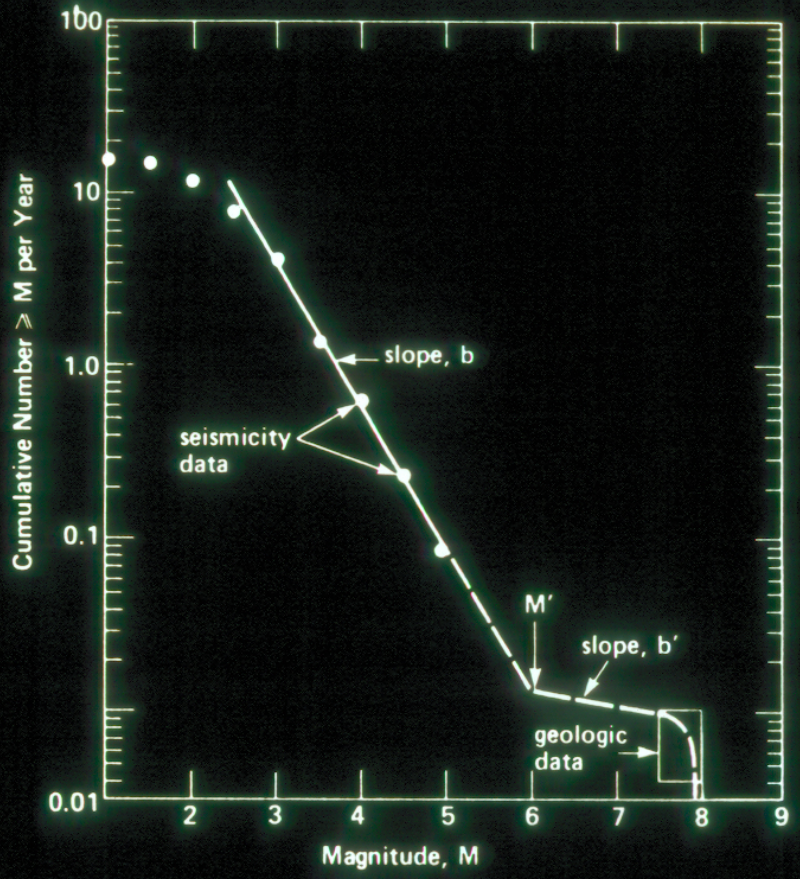
CHARACTERISTIC EARTHQUAKE MODEL



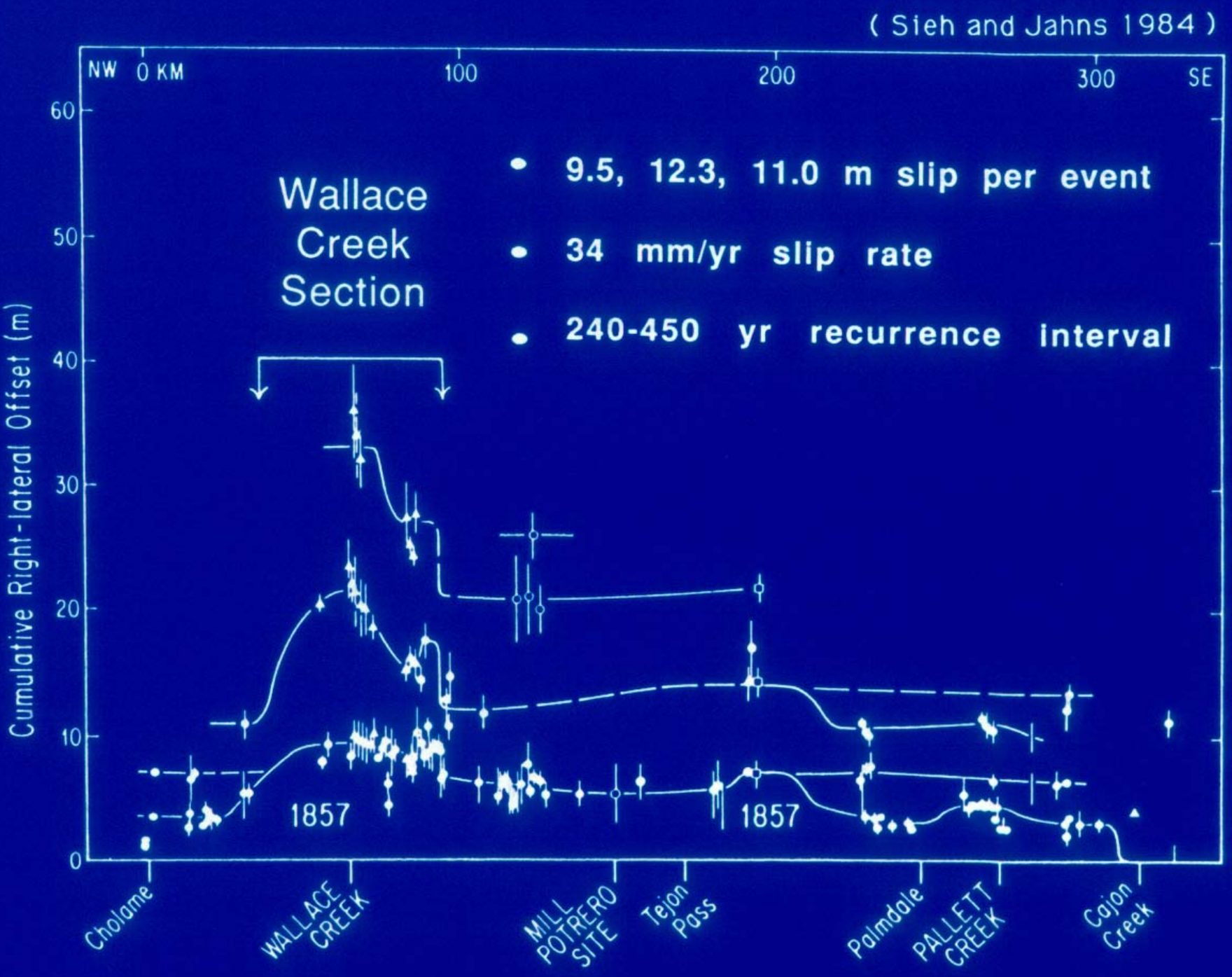
(Modified from Schwartz and Coppersmith, 1984)



FAULT–SPECIFIC RECURRENCE



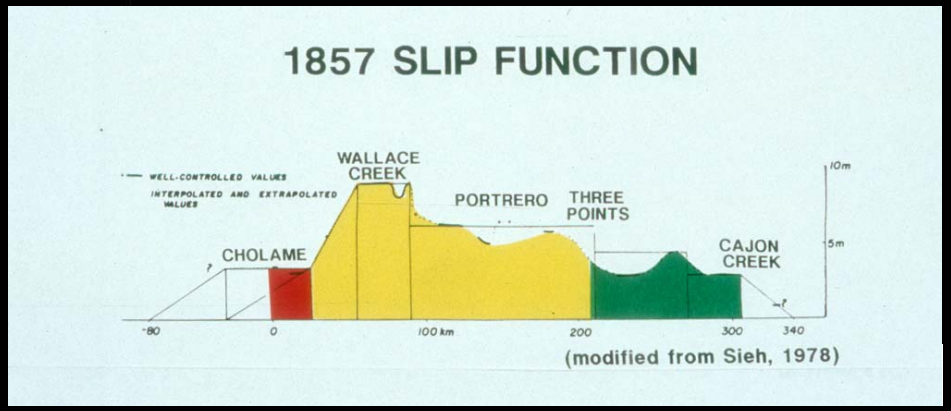
SCHWARTZ AND COPPERSMITH:

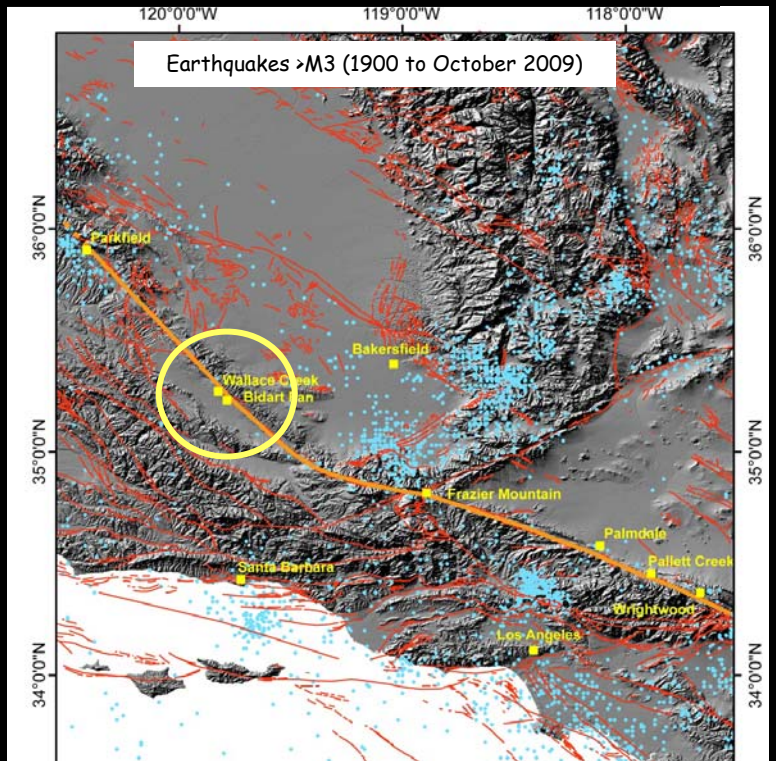

(Sieh and Jahns 1984)
NW
0 KM
100
200
300
SE
Wallace Creek Section
• 9.5, 12.3, 11.0 m slip per event
• 34 mm/yr slip rate
• 240-450 yr recurrence interval
Cumulative Right-lateral Offset (m)
0
10
20
30
40
50
60
1857
1857
Cholame
WALLACE CREEK
MILL POTRERO SITE
Tejon Pass
Palmdale
PALLETT CREEK
Cajon Creek

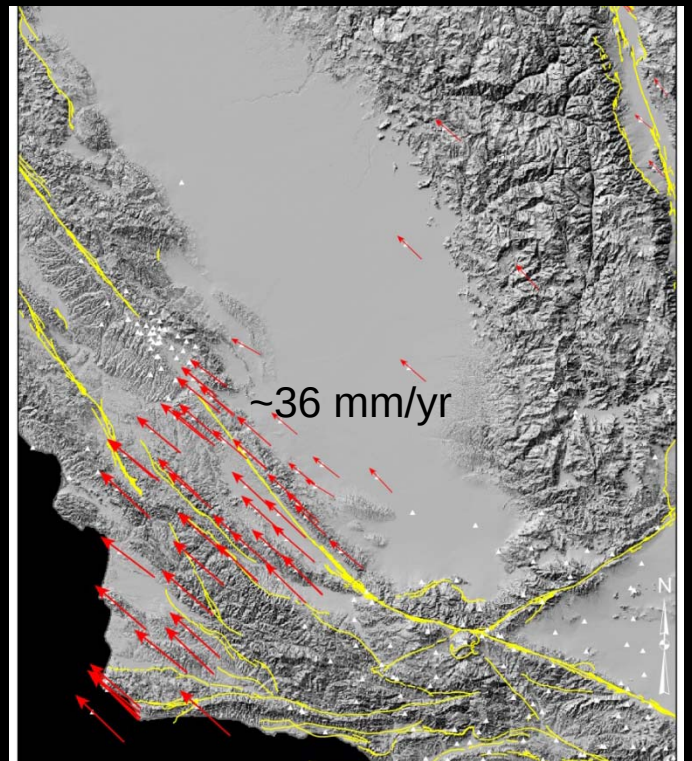
Implications

- Relatively low probability of Carrizo rupture
- Carrizo segment controls occurrence of largest 1857-type EQs
- Smaller or larger than 1857 M Carrizo EQs not likely

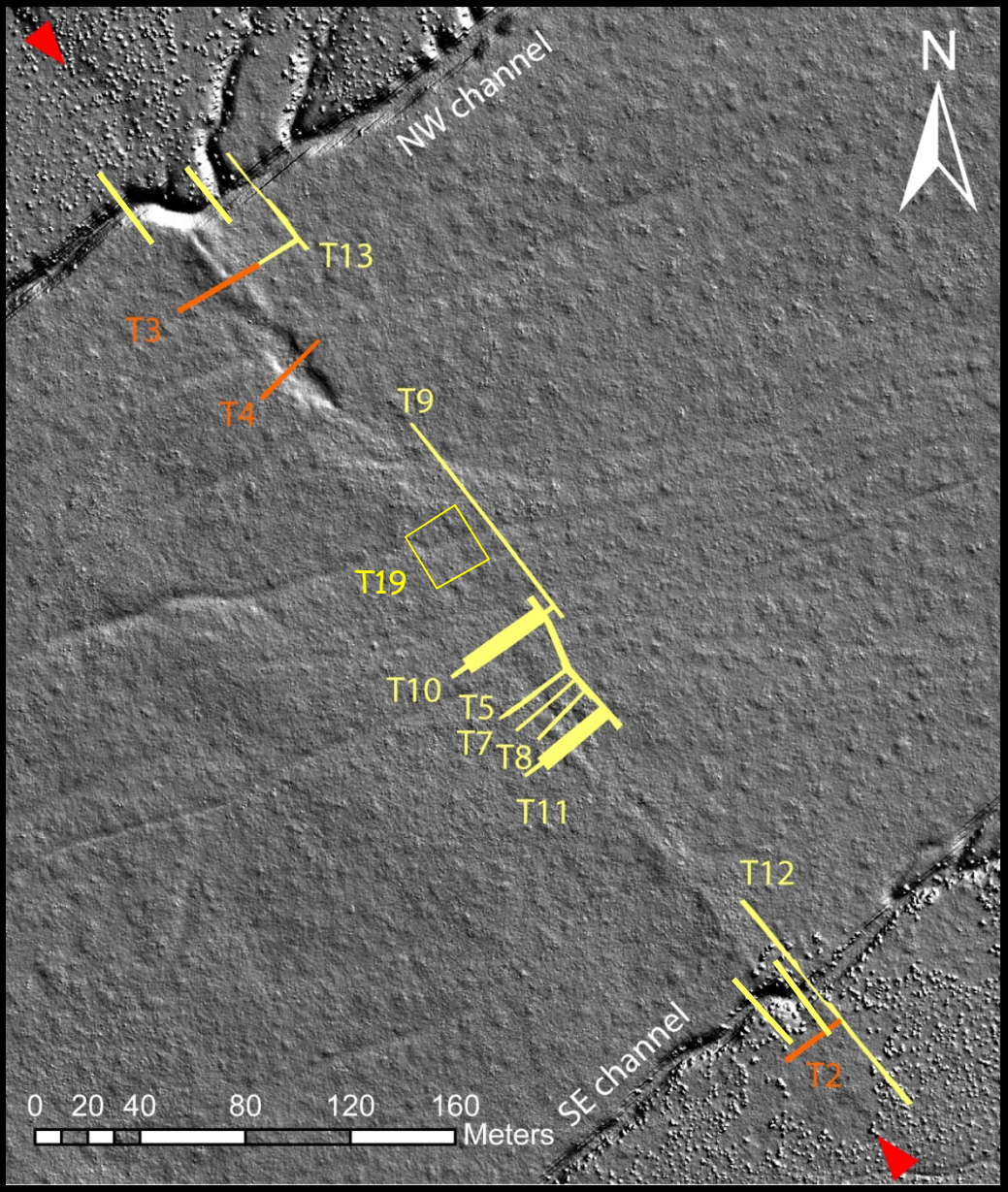
Seismicity and strain







BIDART FAN

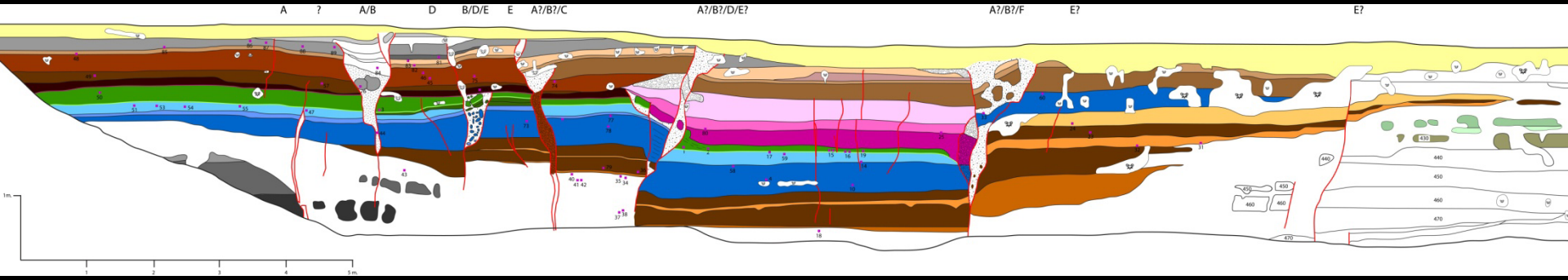


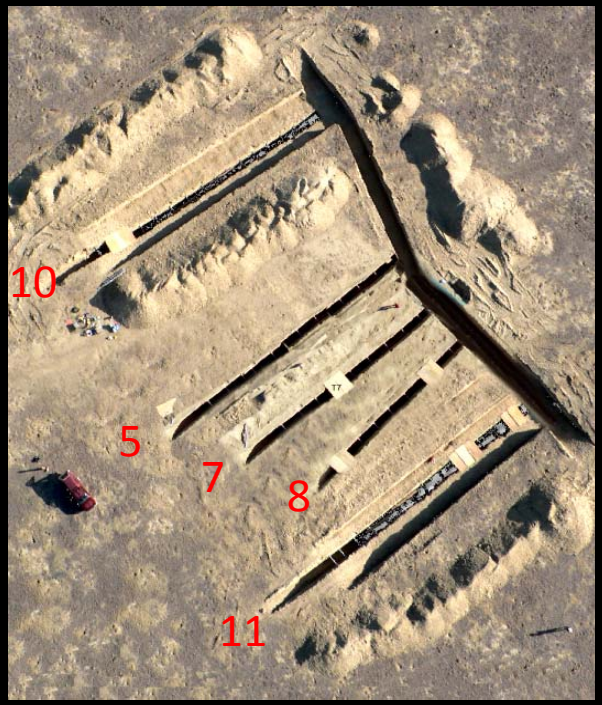
Research Goals:
- Expand paleoearthquake record
- Obtain ages of piercing lines
- Obtain slip per-event

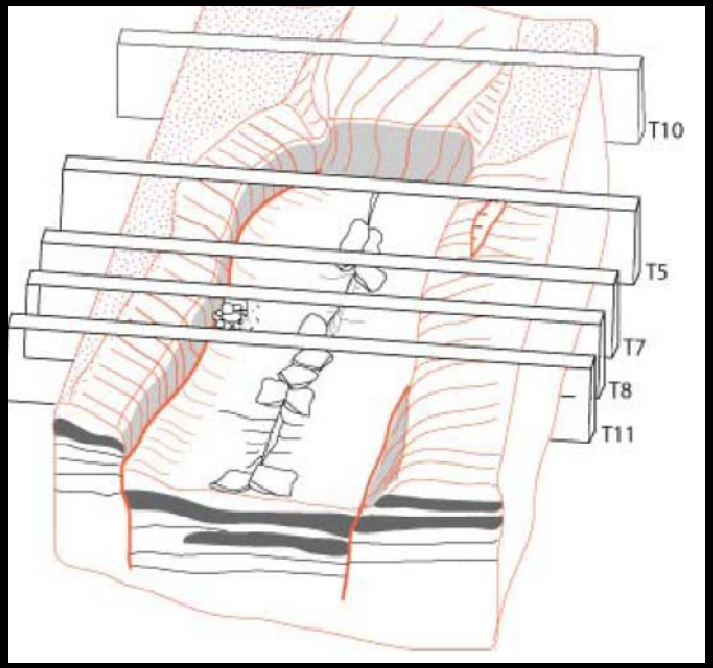
Methods:
- Lots of trenches
- C14 dating
- Paleoclimate record
- Detailed "B4" Lidar data analysis

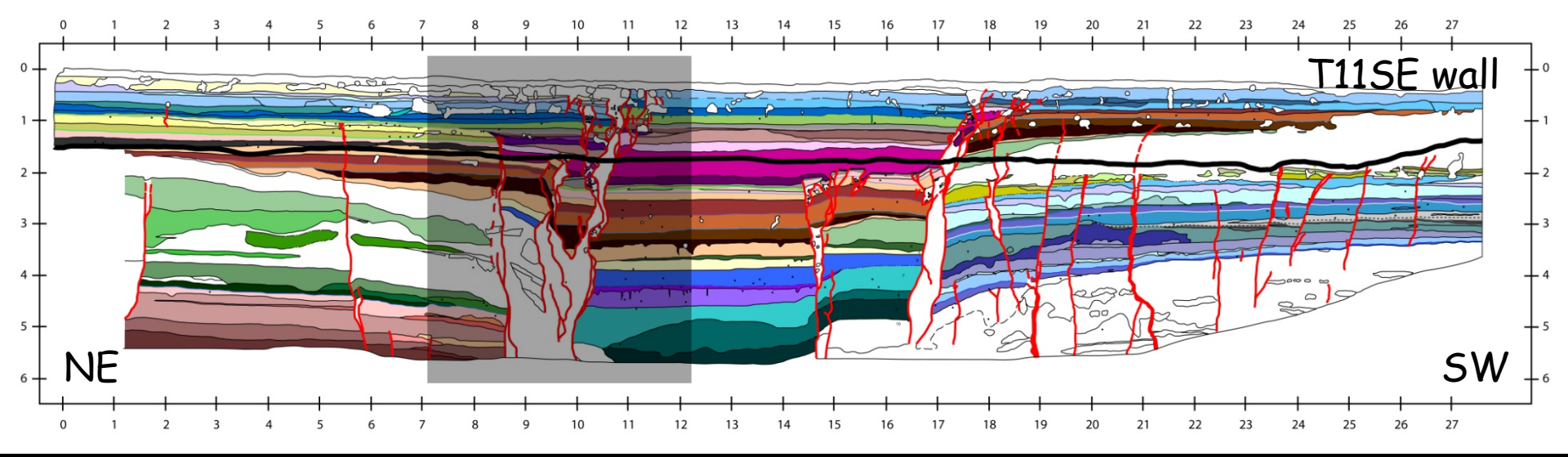
Data collection

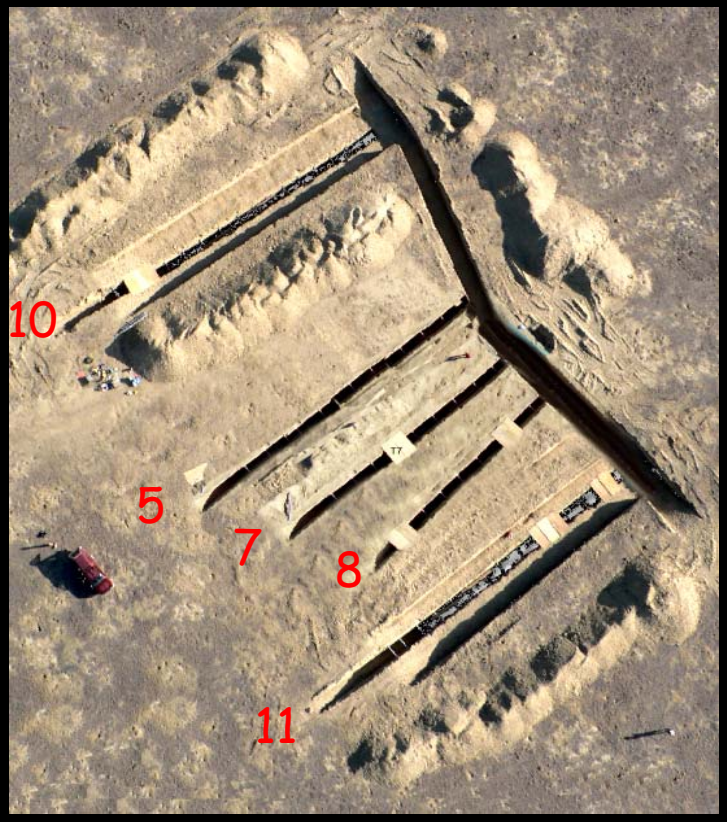
6 Ruptures A.D. 1360 – 1857 in Filled Sag Pond

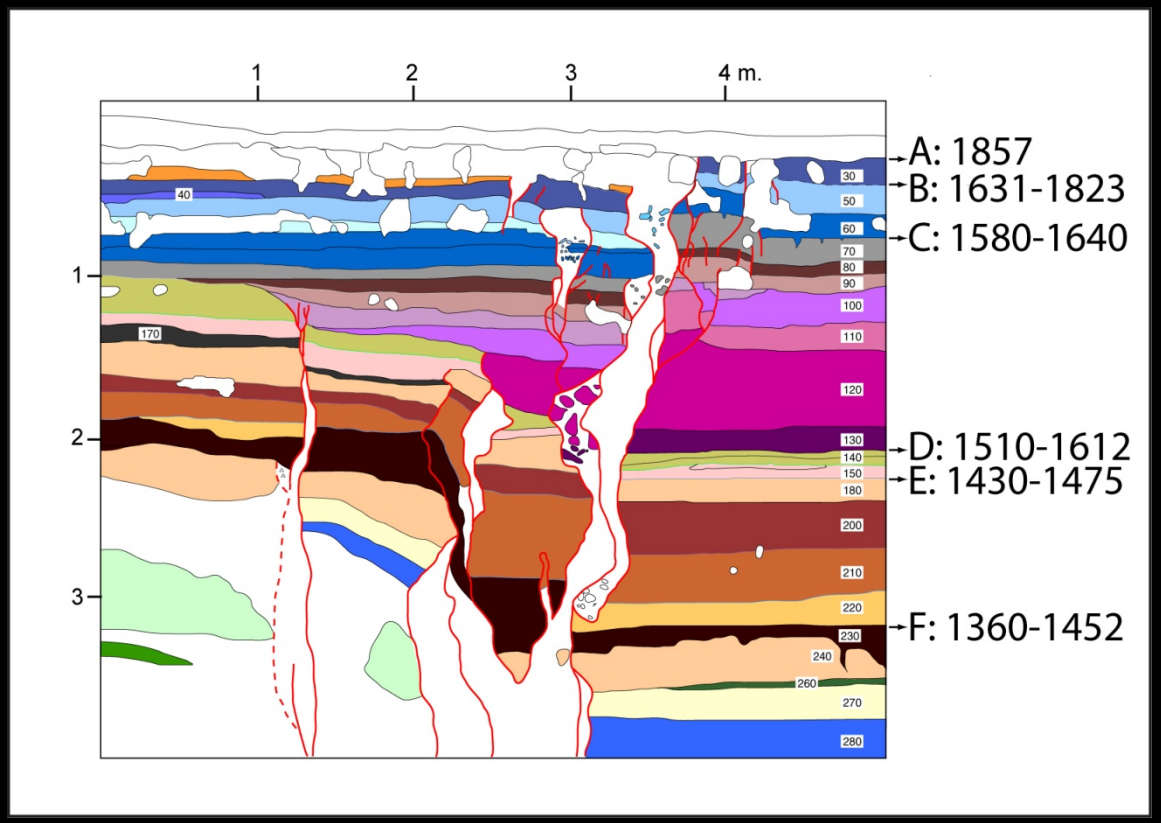


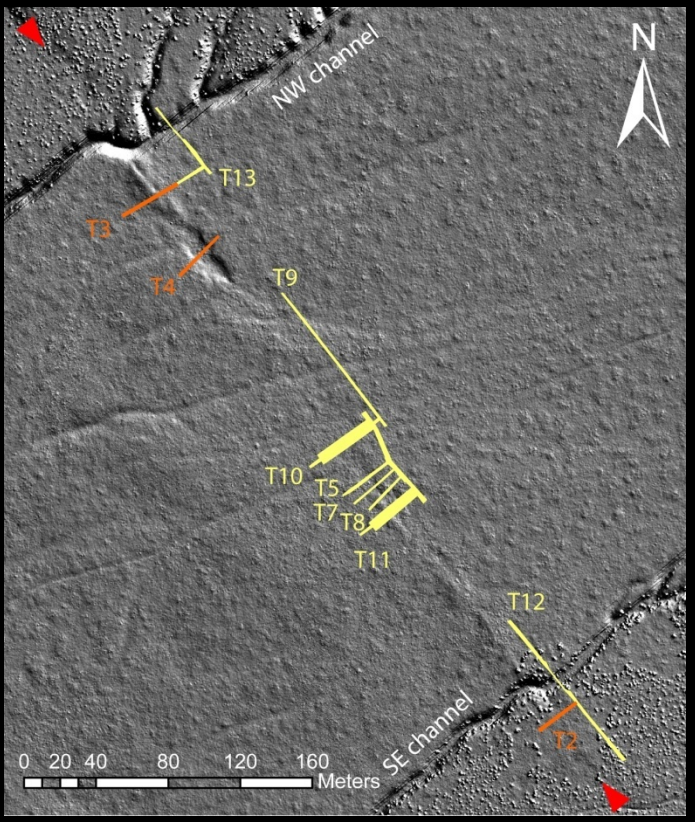





T11SE wall
NE
SW


10
5
7
8
11

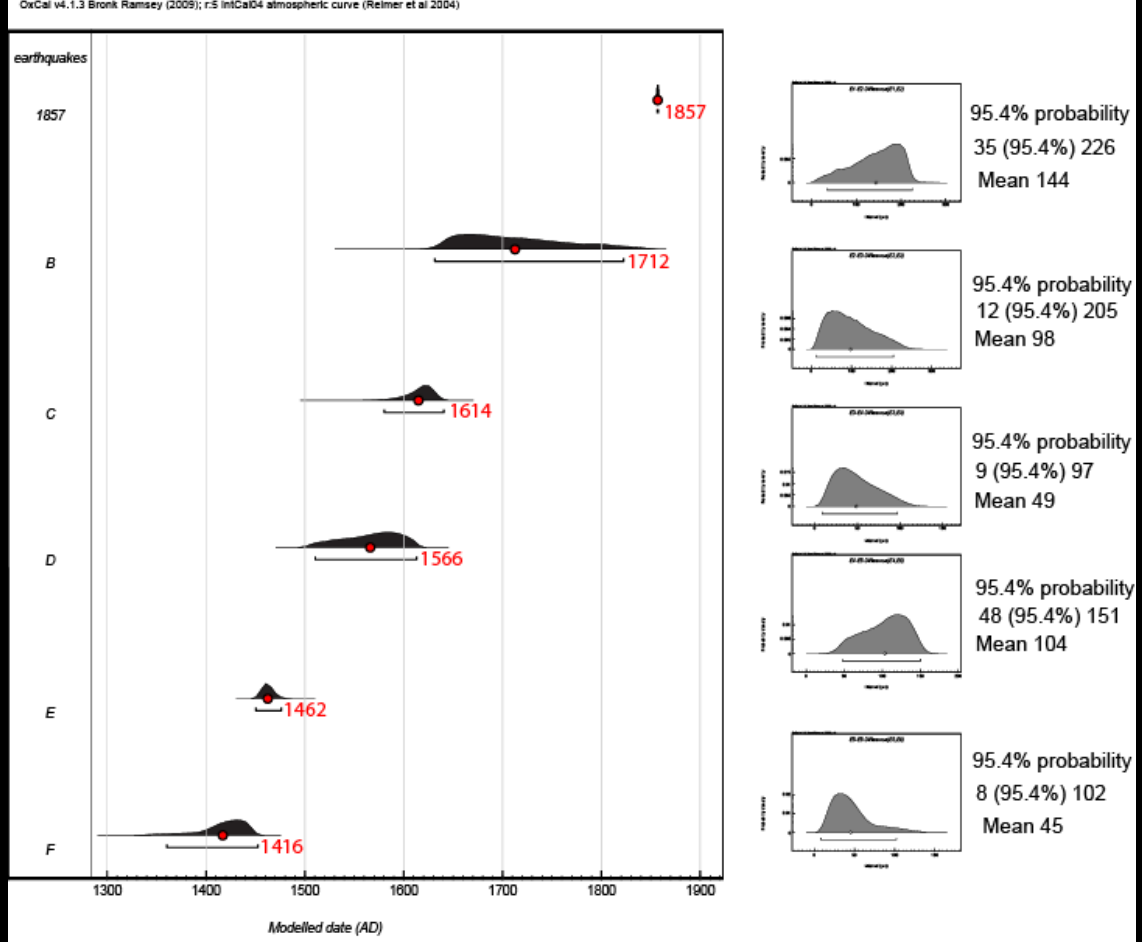

1
2
3
4 m.
A: 1857
B: 1631-1823
C: 1580-1640
D: 1510-1612
E: 1430-1475
F: 1360-1452

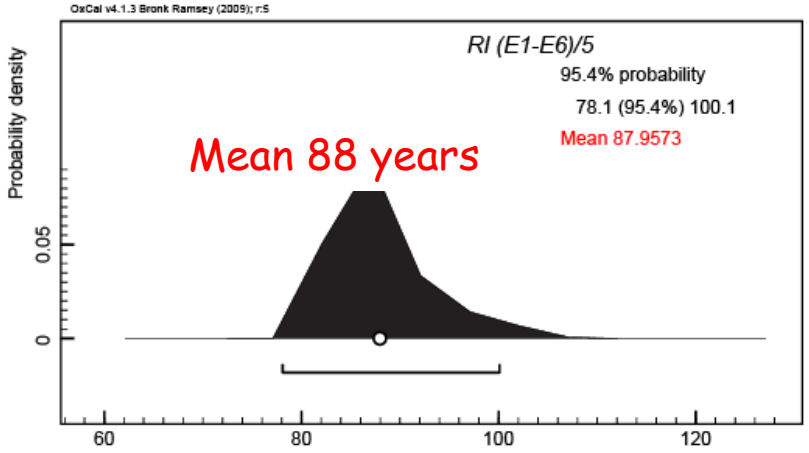


Events	Dates	Events	Dates
A	1857	A	1857
B	1631-1823	B	1640-1857
C	1580-1640	C	1545-1630
D	1510-1612	D	1370-1425
E	1430-1475	E	1285-1340
F	1360-1452	F	500-1250
G?	1285-1340	G	500-1250

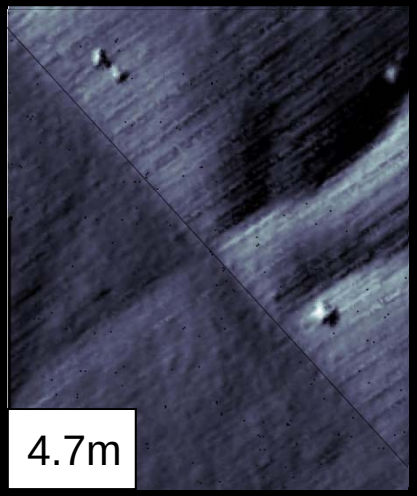
From Akciz et al., 2009

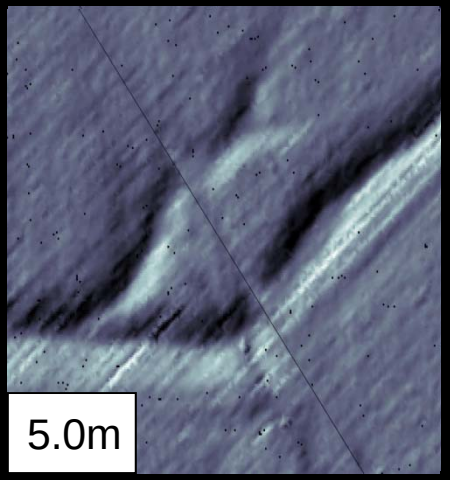
New earthquake chronology at the Bidart Fan Site.

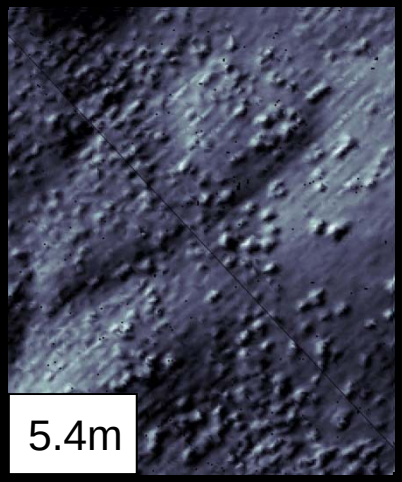

OxCal v4.1.3 Bronk Ramsey (2009); r:5 IntCal04 atmospheric curve (Reimer et al 2004)
earthquakes
1857
1857
B
1712
C
1614
D
1566
E
1462
F
1416
1300
1400
1500
1600
1700
1800
1900
Modelled date (AD)
95.4% probability
35 (95.4%) 226
Mean 144
95.4% probability
12 (95.4%) 205
Mean 98
95.4% probability
9 (95.4%) 97
Mean 49
95.4% probability
48 (95.4%) 151
Mean 104
95.4% probability
8 (95.4%) 102
Mean 45

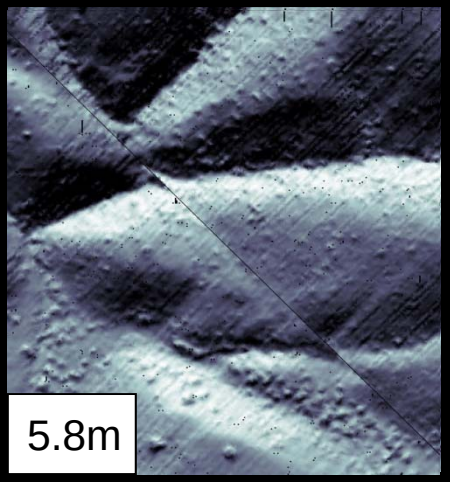

OxCal v4.1.3 Bronk Ramsey (2009); r:5
RI (E1-E6)/5
95.4% probability
78.1 (95.4%) 100.1
Mean 88 years
Mean 87.9573
Probability density
0.05
0
60
80
100
120

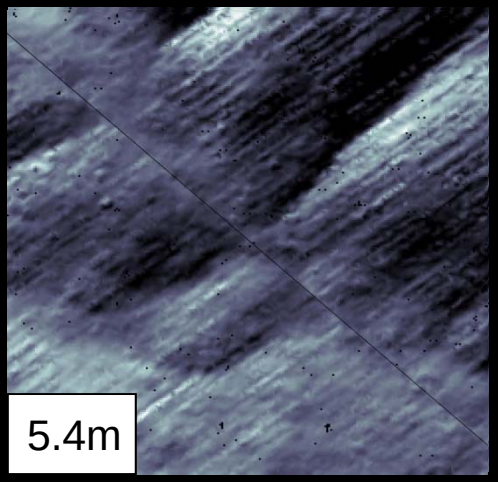
Carrizo Plain, 1857 Offsets



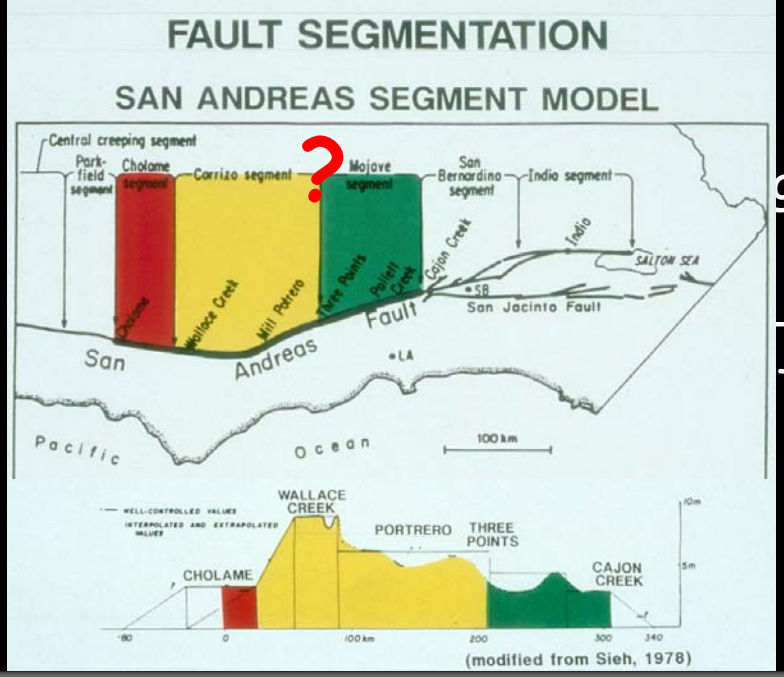


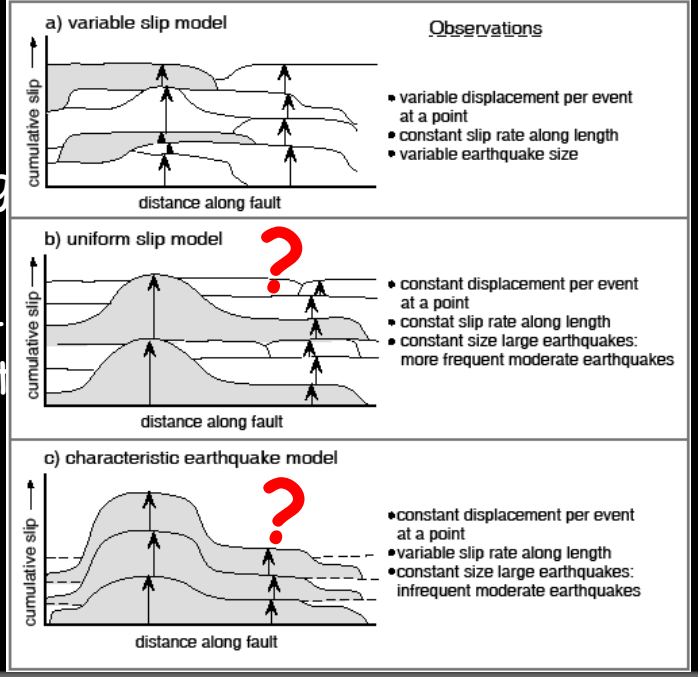


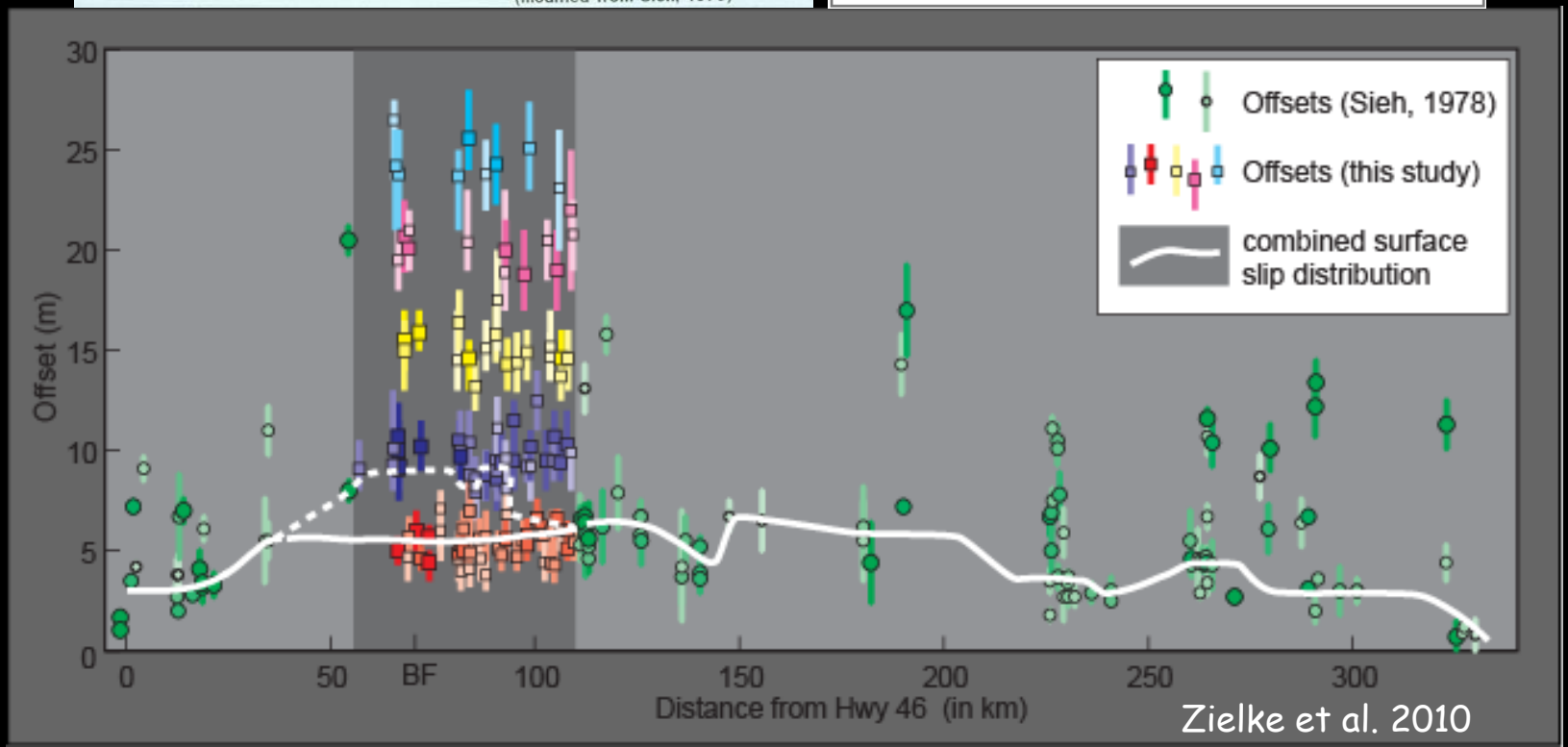




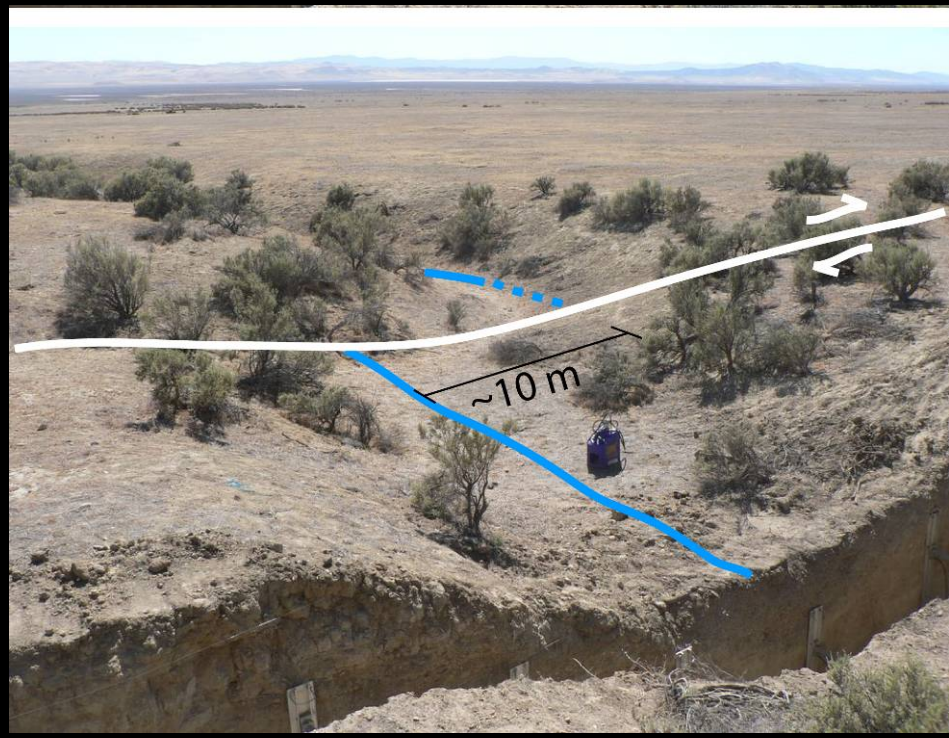
From Zielke et al. 2010

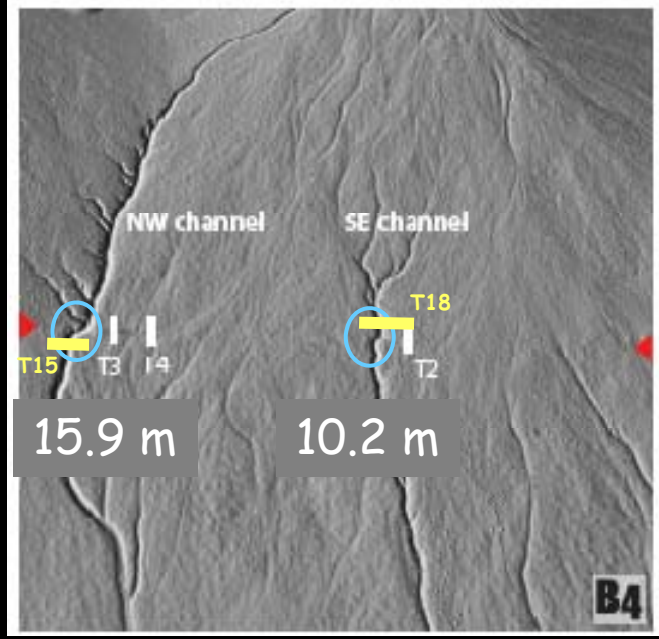

FAULT SEGMENTATION
SAN ANDREAS SEGMENT MODEL
Central creeping segment
Park-field segment
Cholame segment
Carrizo segment
?
Mojave segment
San Bernardino segment
Indio segment
Dicalma
Wallace Creek
Mill Potrero
Three Points
Pallett Creek
Cajon Creek
Indio
SALTON SEA
SB
San Jacinto Fault
San Andreas Fault
LA
Pacific ocean
100 km
WELL-CONTROLLED VALUES
INTERPOLATED AND EXTRAPOLATED VALUES
WALLACE CREEK
PORTRERO
THREE POINTS
CHOLAME
CAJON CREEK
10m
5m
-80
0
100 km
200
300
340
(modified from Sieh, 1978)

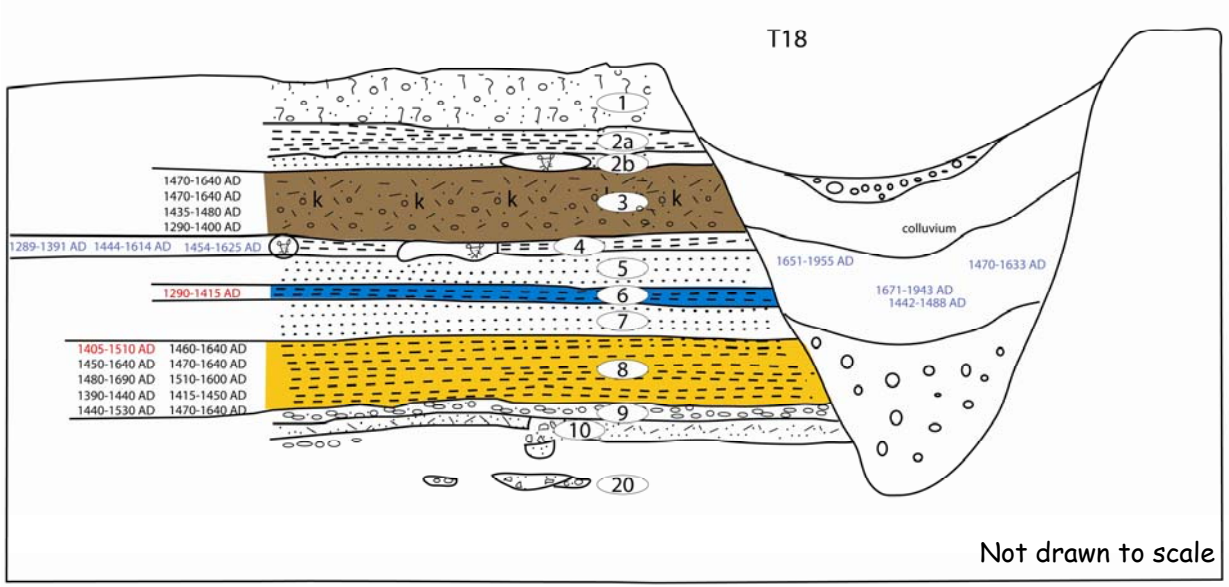

a) variable slip model
Observations
cumulative slip
distance along fault
• variable displacement per event at a point
• constant slip rate along length
• variable earthquake size
b) uniform slip model
?
cumulative slip
distance along fault
• constant displacement per event at a point
• constat slip rate along length
• constant size large earthquakes: more frequent moderate earthquakes
c) characteristic earthquake model
?
cumulative slip
distance along fault
•constant displacement per event at a point
•variable slip rate along length
•constant size large earthquakes: infrequent moderate earthquakes


Offset (m)
0
5
10
15
20
25
30
0
50
BF
100
150
200
250
300
Distance from Hwy 46 (in km)
Offsets (Sieh, 1978)
Offsets (this study)
combined surface slip distribution
Zielke et al. 2010

Bidart Fan southeast channel is offset ~10 m
How many earthquakes?



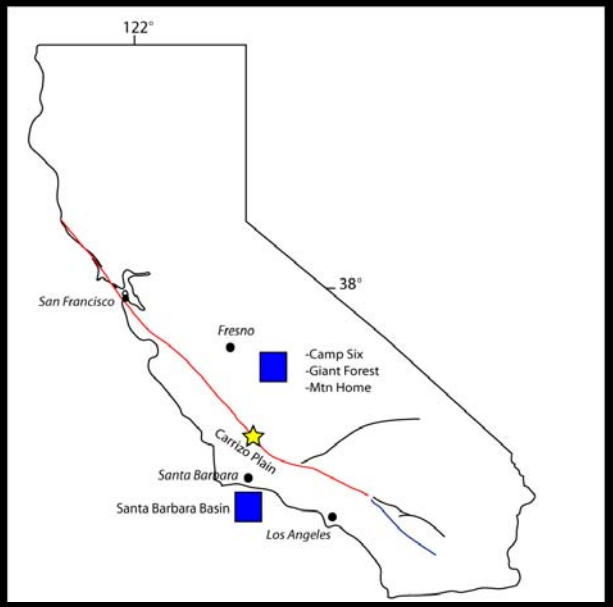




Limited deposition since A.D. 1470-1640

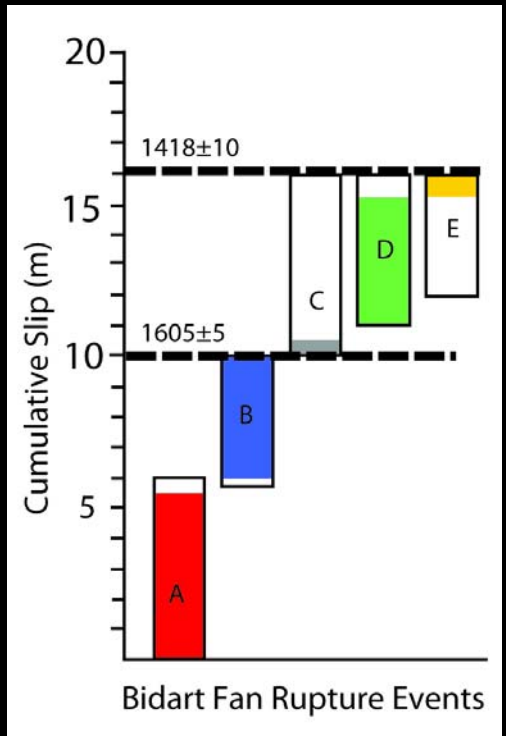
1418 ± 10

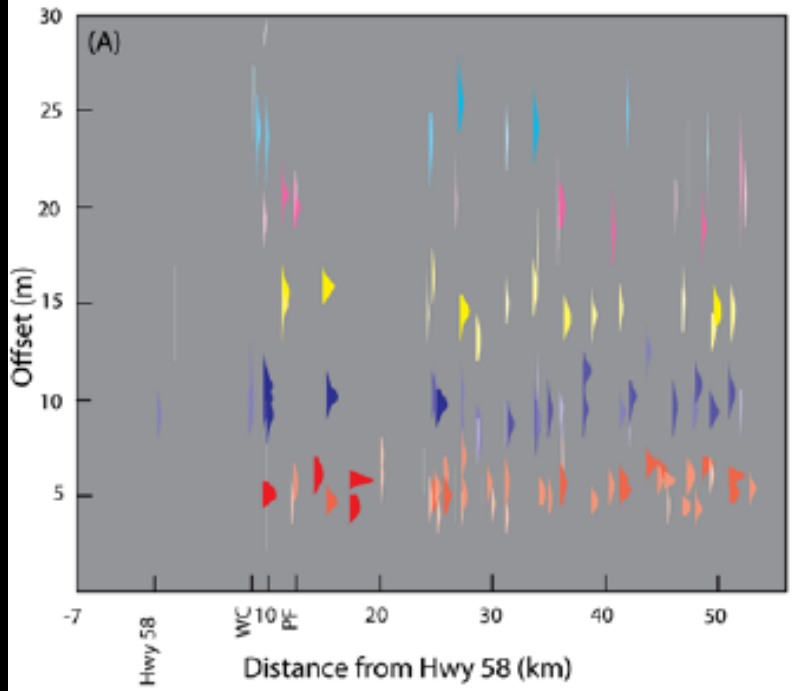
1605 ± 5

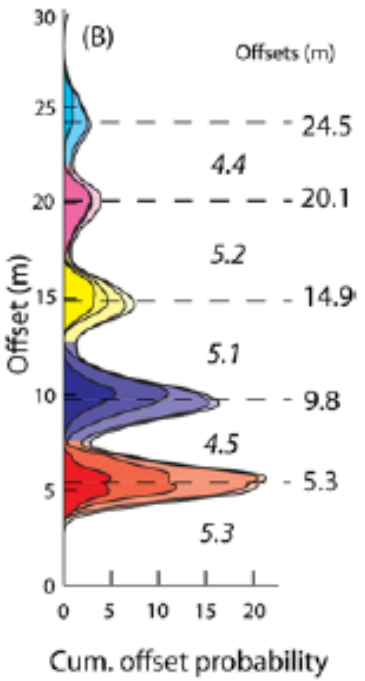


Check:
1857 – 1605 =
252 yrs.
252 yrs * 36
mm/yr = ~9 m

1857 – 1418 =
439 yrs.
439 yrs * 36
mm/yr = ~16





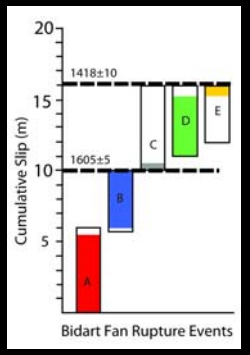


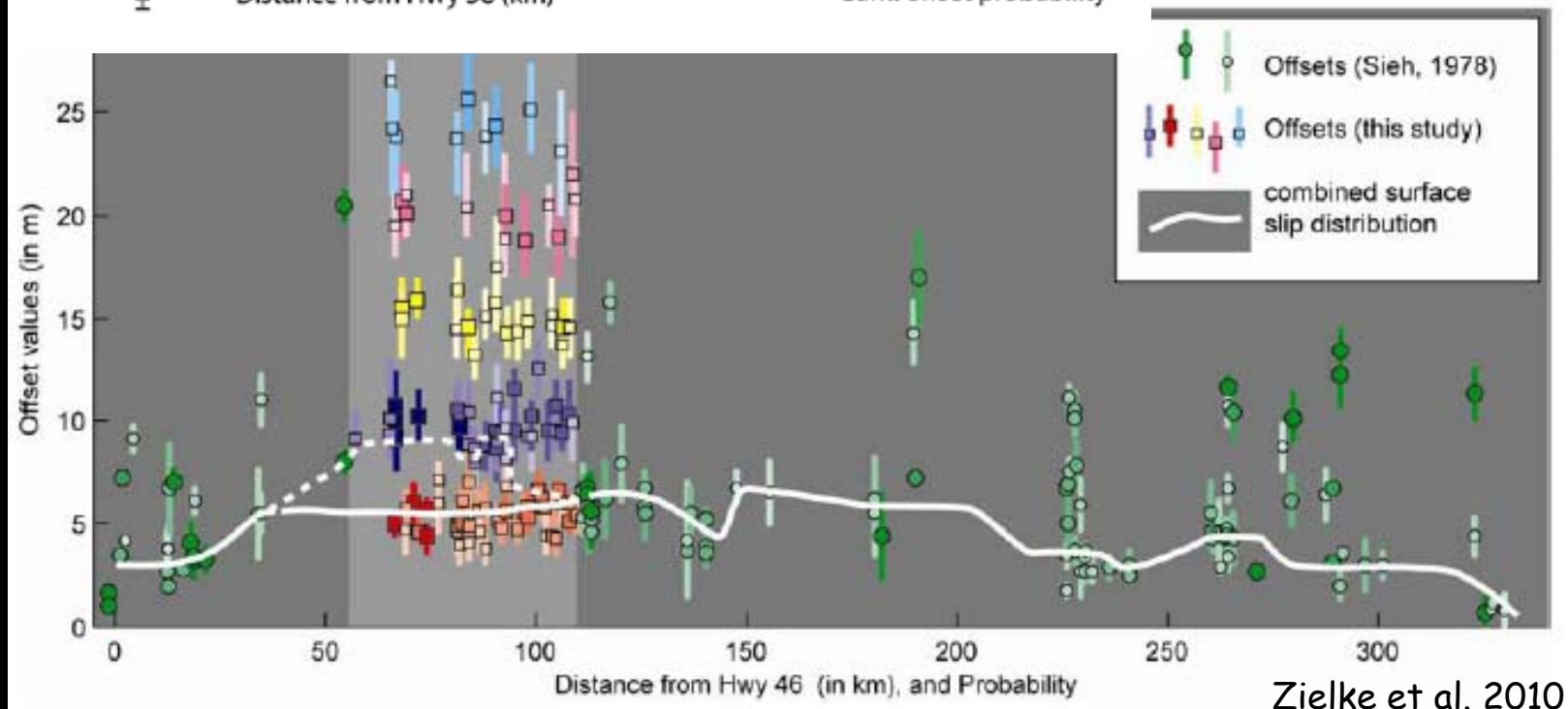
?

A, B, C, D, E

A+B

A (1857)

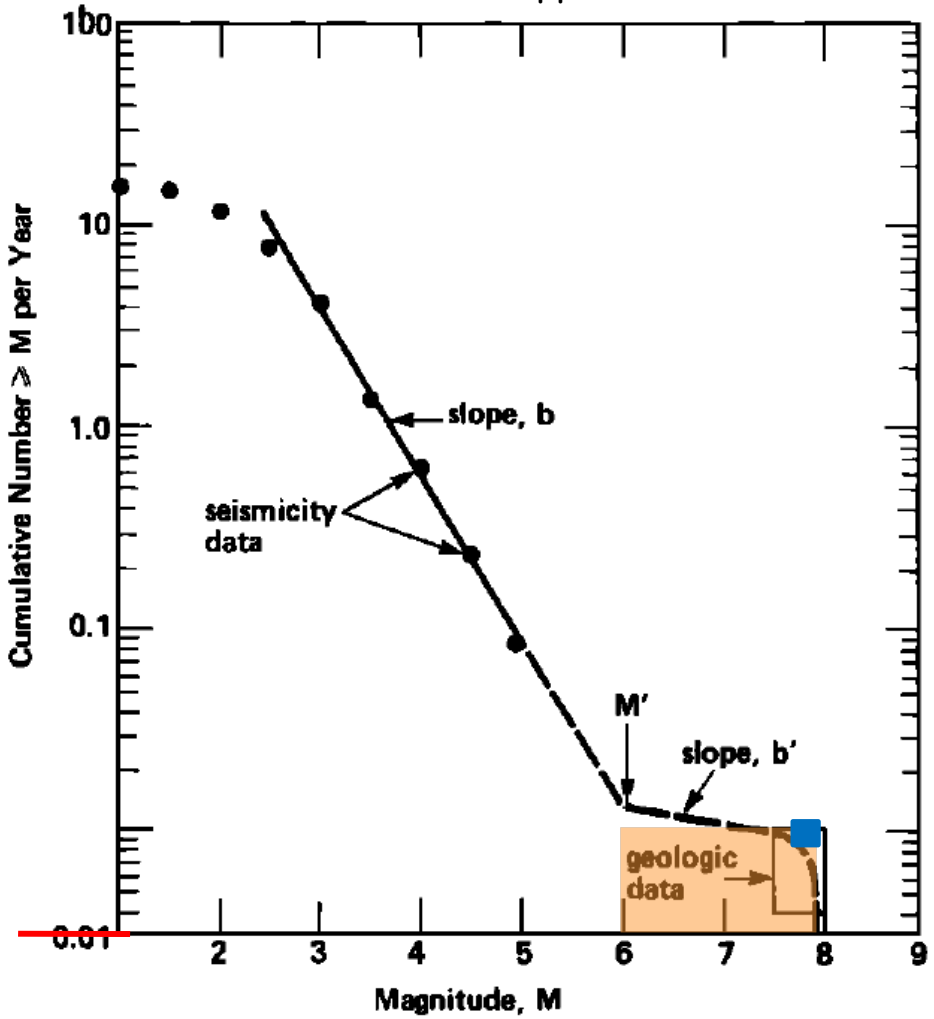


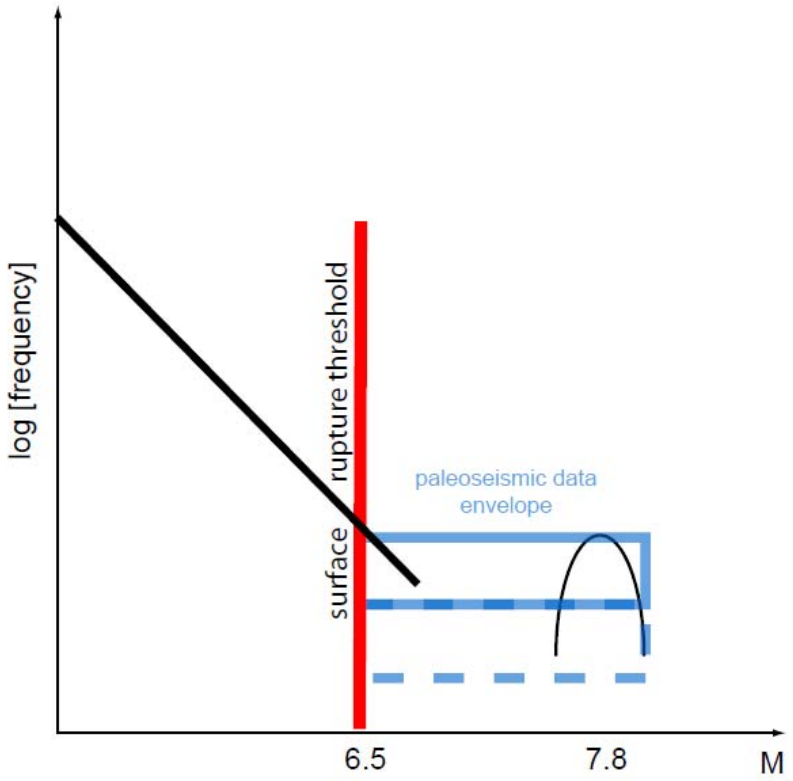


Zielke et al. 2010

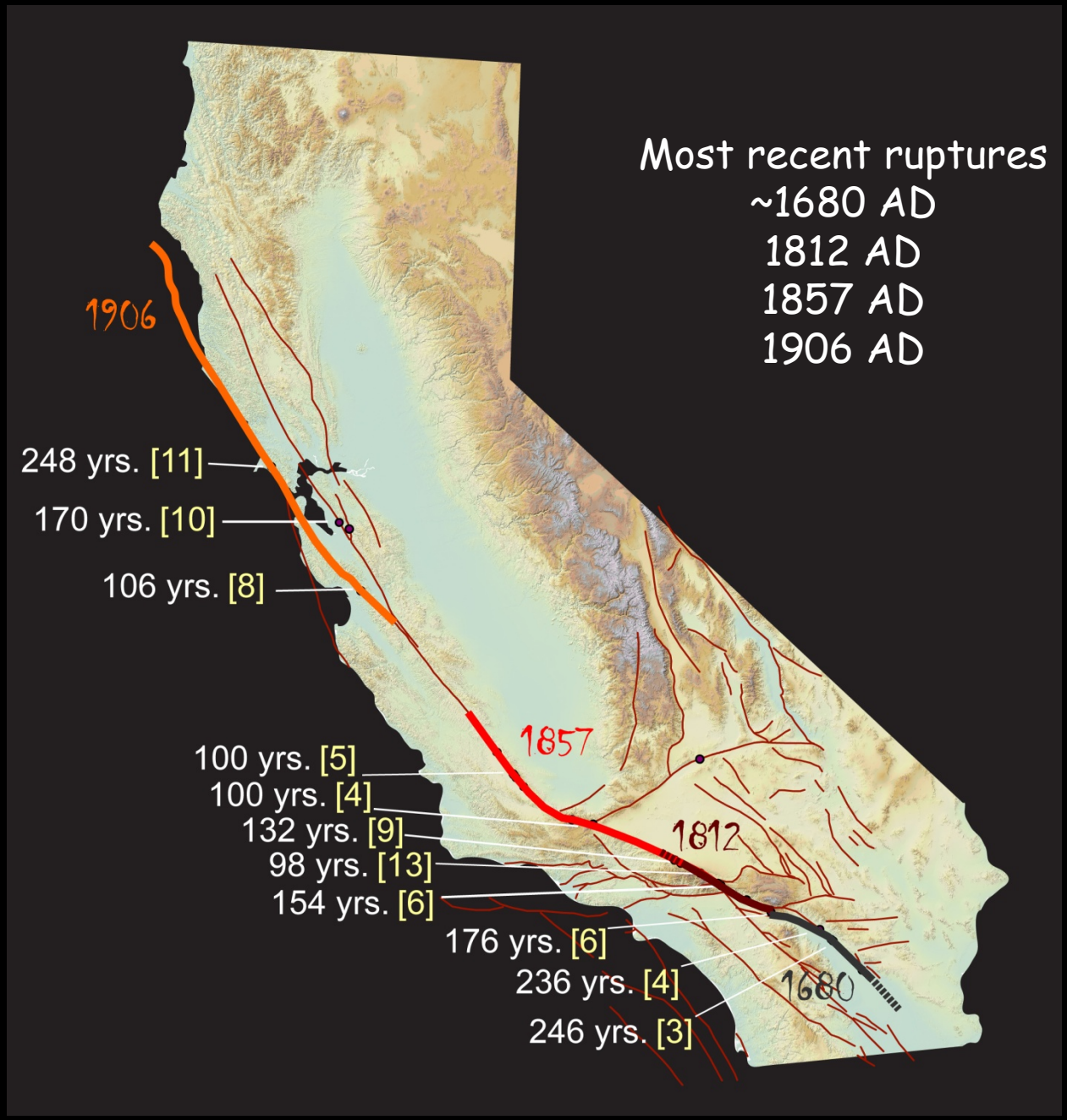
What does new Carrizo data suggest?

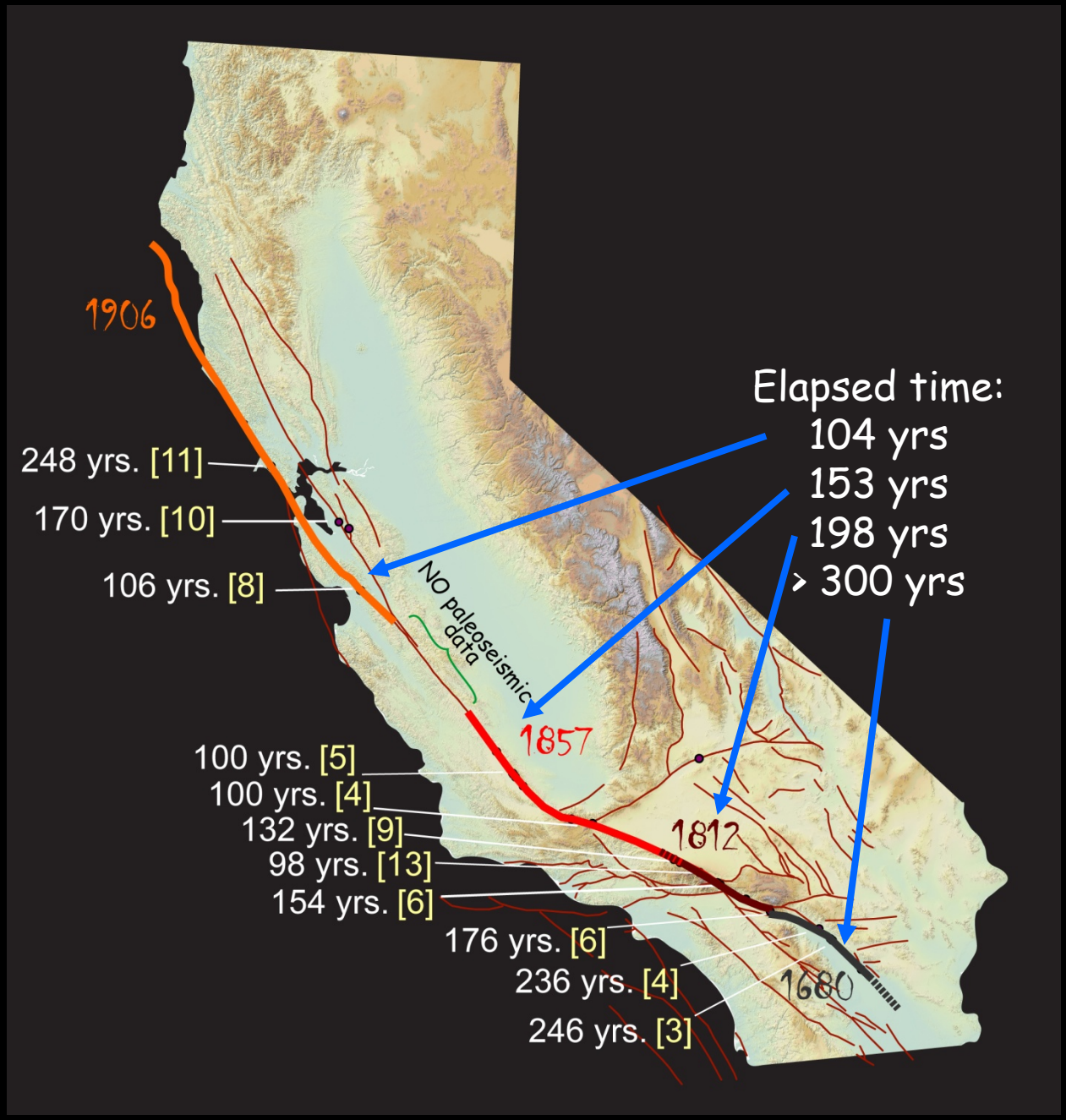
From Schwartz & Coppersmith, 1984





Frequent, >M6 earthquakes in the Carrizo


Most recent ruptures
~1680 AD
1812 AD
1857 AD
1906 AD
1906
248 yrs. [11]
170 yrs. [10]
106 yrs. [8]
1857
100 yrs. [5]
100 yrs. [4]
132 yrs. [9]
98 yrs. [13]
154 yrs. [6]
1812
176 yrs. [6]
236 yrs. [4]
246 yrs. [3]
1680


1906
248 yrs. [11]
170 yrs. [10]
106 yrs. [8]
NO paleoseismic data
1857
100 yrs. [5]
100 yrs. [4]
132 yrs. [9]
98 yrs. [13]
154 yrs. [6]
1812
176 yrs. [6]
236 yrs. [4]
246 yrs. [3]
1680
Elapsed time:
104 yrs
153 yrs
198 yrs
> 300 yrs

SUMMARY

- At Bidart Fan San Andreas Fault ruptured 7 times between 1310±30 AD and 1857.
- Mean interval is 88 ± 41 years since 1360.
- Slip per earthquake was variable, not characteristic
- 1857 and penultimate rupture each ~ 5 m slip
- Repetition of 1857-like ruptures is possible, but smaller magnitude or different rupture pattern also occurred.
- No compelling evidence for Carrizo "segment" as defined by slip gradients and different recurrence intervals.

Conclusions and Questions

- Large magnitude, large slip and smaller slip earthquakes (variable slip)
  - Current strain accumulation ~equal to maximum released (in 1857).
- Rupture average recurrence 88±41 yrs
- Elapsed time since 1857 is 153 yrs
- High probability of Carrizo rupture?
  - Large or moderate magnitude?

The End?

THANK YOU

USGS

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an NSF + USGS center